BELLCOMM, INC.
955 L'ENFANT PLAZA NORTH, S.W. WASHINGTON, D.C. 20024

B70 03023

SUBJECT: Lurain Effects on the LM Trajectory and Landing Point Designator Accuracy for Apollo 13 - Case 310

DATE: March 9, 1970

FROM: G. M. Cauwels
F. LaPiana

ABSTRACT

[redacted]

This study evaluates the effects of the landing site approach lurain on trajectory shape and LPD accuracy for Apollo 13. Simulations using the currently targeted landing site, an uprange target, and data from the Operational Trajectory for Apollo 13 are compared.

For the current site, trajectory droop brings the line-of-sight to the landing site near the 10° sun line for an April 11 launch. The most severe visibility conditions occur at about 7500 ft. range and 1400 ft. altitude.

Lurain effects on the LPD system are very pronounced. For the current site, a 3600 ft. apparent landing site displacement occurs at 47 seconds into the visibility phase. The angular LPD error reaches 2.95°. These effects could cause erroneous LPD redesignations to be made which would worsen the trajectory droop problem and incur an additional ΔV expenditure.

The recently announced plan for a 900 ft. uprange LPD redesignation was evaluated. A 2° line-of-sight improvement and a 31 fps ΔV saving are made. The visibility time is shortened by 7 seconds.

(NASA-CR-109782) LURAIN EFFECTS ON THE LM TRAJECTORY AND LANDING POINT DESIGNATOR ACCURACY FOR APOLLO 13 (Bellcomm, Inc.) 14 p

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MEMORANDUM FOR FILE

The purpose of the study is to evaluate the effects of the Fra Mauro landing site approach lurain on trajectory shape and LPD accuracy. During the braking and visibility phases of the LM landing maneuver, the landing radar (LR) is used to update the estimate of the LM position vector. When the lurain altitude is different from that at the initially targeted landing site, the LR data causes an altitude error (relative to the landing site) in the LM guidance computer (LGC).

Since the Apollo science sites are surrounded by a much more irregular lurain than the landing sites of Apollo 11 and 12, the effects have become much more pronounced than formerly. Data used for this analysis was generated with the latest lurain profile for Fra Mauro [1]* adjusted in range and elevation for two possible relocations of the landing site. In Case 1, the site is approximately 5000 feet uprange [2] of the site used in Reference 1, and for Case 2, the landing site is 2160 feet uprange of the site used in Reference 1. Case 2 is the currently targeted landing site; Case 1 is included for comparison purposes.

The lurain profile was utilized in the Bellcomm Powered Flight Performance Simulator computer program for the LM landing trajectory. The trajectory parameters from Apollo 12 [3] have been used and are those planned for use on Apollo 13.

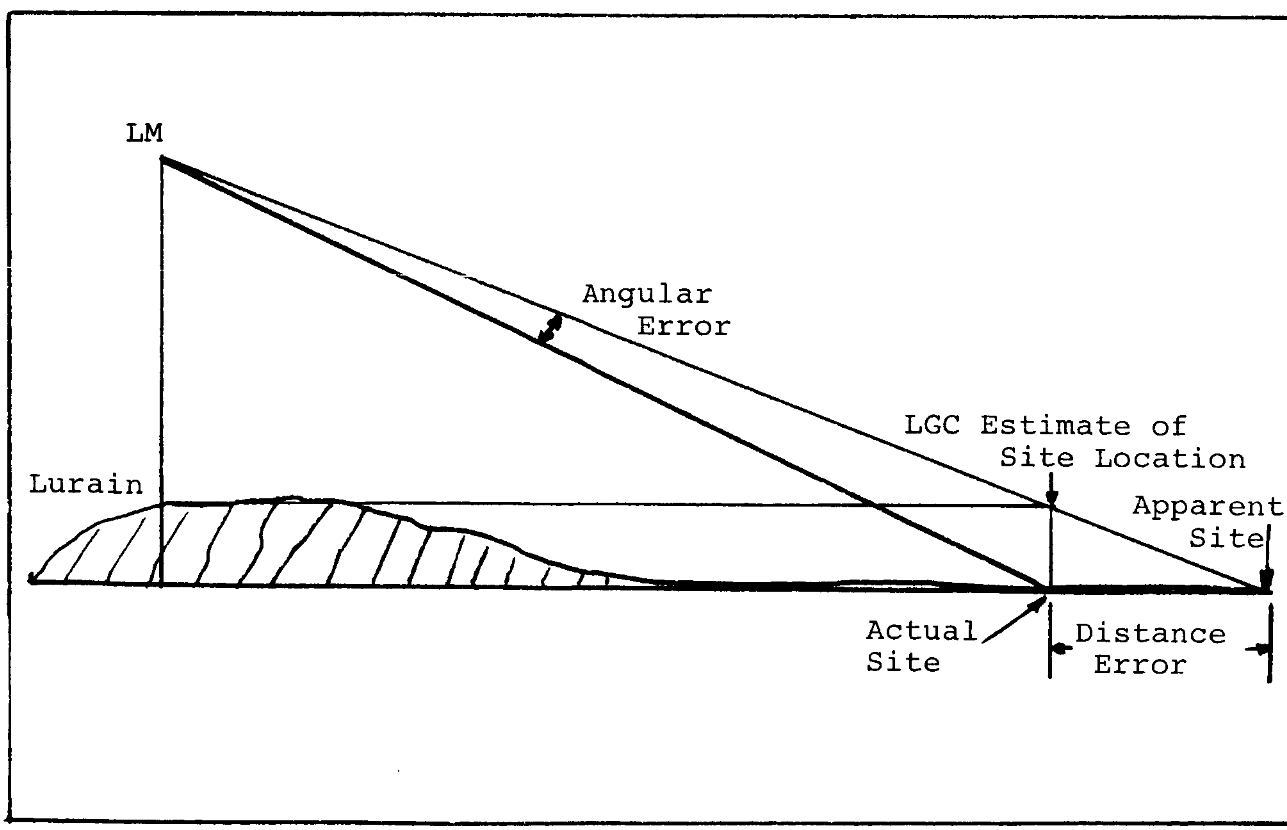
The trajectory profiles relative to the lurain profile are shown in Figures 1 and 2. In both cases the pronounced droop brings the line-of-sight to the landing site near the 10° sun line for an April 11 launch. The trajectory droop results partly from the lurain (through LR measurements) and partly from the fact that on Apollo 12 and subsequent

*Numbers in brackets refer to references.

missions, the trajectory targeting was modified to provide a nearly constant landing point designator angle during the visibility phase.

When the look angle is within about 2° of the sun elevation angle, visual washout can become severe. The most severe visibility conditions for Case 1 occur at an altitude of 1300 feet and range of 7500 feet. For Case 2, this occurs at about the same range, but at a slightly higher altitude as shown in Figure 2. The droop is accentuated by the relocation of the landing site closer to the crest of the ridge. The Operational Trajectory [4] did not show such a pronounced effect.

As was mentioned before, any lurain altitude different from that of the site over which the LM goes during these phases causes an LGC altitude error to be induced via the LR. Since the LGC calculates the LPD angle as a function of altitude, this causes the angular and corresponding distance errors shown below.



Angular and Distance Errors Produced by Lurain Elevation-LR Inputs to LGC

Figures 3 and 4 give the LPD angle vs. time and the line-of-sight angle to the landing site for Cases 1 and 2.

The distance error is how far away from the actual LGC designated site that the astronaut will look when using the LPD calculated look angle. The distance error as a function of time is shown in Figures 5 and 6. In Case 1, the 4400 feet distance error occurs at 56 seconds into the visibility phase and for Case 2, the 3600 foot error occurs at 47 seconds. Either case could cause a large erroneous site redesignation to be made. This could be especially detrimental in cases such as this, in which the apparent site is downrange of the actual site, since the early erroneous redesignations would be uprange, and later, correcting redesignations would be downrange. This combination of redesignations could cause a trajectory droop greater than that shown in Figures 1 and 2 and could incur a large ΔV expenditure.

Figures 7 and 8 show the LPD indicated angular error caused by the lurain plotted as a function of time. This error is the difference between the LPD calculated look angle and the measured look angle to the actual LGC designated site. Positive values indicate that the apparent site is above the actual site in the window.

The trajectory droop problem could be corrected either by changing the trajectory parameters and reshaping for a better minimum look angle or by using a pseudo target downrange of the landing site and then "nominally" making a short redesignation. Both of these techniques would result in a ΔV savings but with the sacrifice of some of the present visibility time of 134 seconds.

At the February 24 Apollo Mission Review, plans to make a short LPD redesignation of about 900 ft. were revealed. This is contingent on the selection of an acceptable site by the astronauts during the visibility phase. A simulation of this has been made, using a one-pulse uprange redesignation at 4000 ft. altitude plus a one-pulse uprange at 800 ft. altitude. This method was necessary because of the LPD redesignation granularity of one-half degree per pulse. This procedure gives an improvement of about 2° in the line of sight up and away from the sun angle by removing some of the trajectory droop. It also gives a ΔV saving of 31 fps from the nominal unredesignated trajectory. The visibility time is shortened by 7 seconds to 127 seconds. The LPD errors are relatively unchanged.

As an interim measure, the LPD angle/distance error problem could be alleviated by using the data in Figure 5 or 6 as a LPD correction factor during the descent.

Preferable techniques for solving both problems are being evaluated for application to Apollo 14. These include LGC contained lurain profiles to be used as LR altitude biases, and landing site adjustment as a function of altitude updates to keep the LPD indicated landing site fixed on the surface of the moon.

G. M. Cauwels

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REFERENCES

1. Memorandum TJ-70-148, "Revised Profile of Fra Mauro", dated January 28, 1970, by Robert O. Hill, TJ3 Photogrammetry MSC.

2. Letter to GLEP Site Selection Subgroup Members, "Apollo 13 Landing Point", dated January 27, 1970 by F. El-Baz, Bellcomm, Inc.

3. Memorandum 69-FM22-247, "H-1 Powered Descent Targets", dated September 1969, by James H. Alphin, MSC.

4. The Spacecraft Operational Trajectory for Apollo 13 (Mission H-2) Vol. 1, January 23, 1970, Mission Planning and Analysis Division MSC.

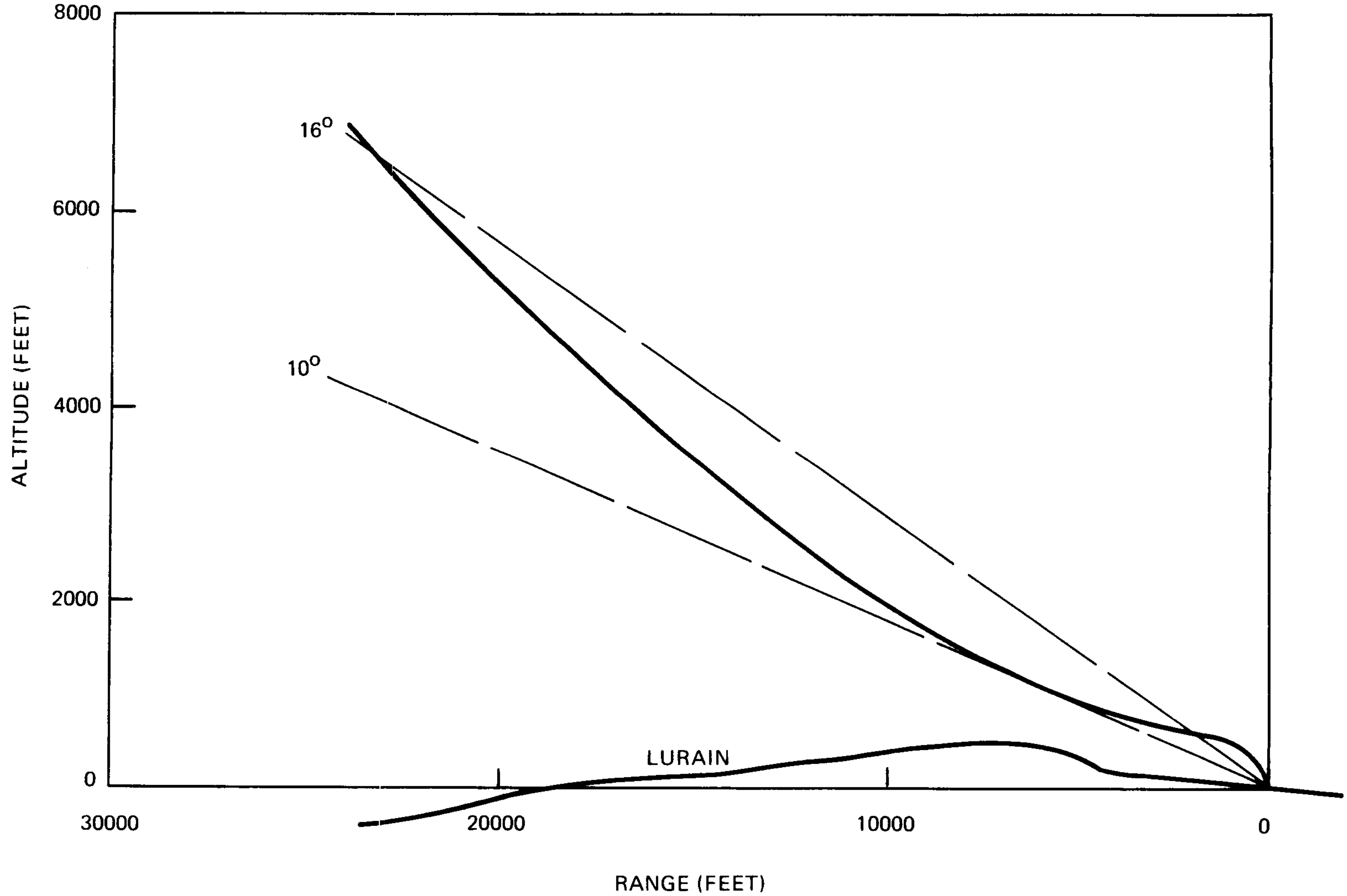

FIGURE 1—TRAJECTORY AND LURAIN PROFILES FOR CASE 1, LANDING SITE MOVED 5000 FT. UPRANGE.

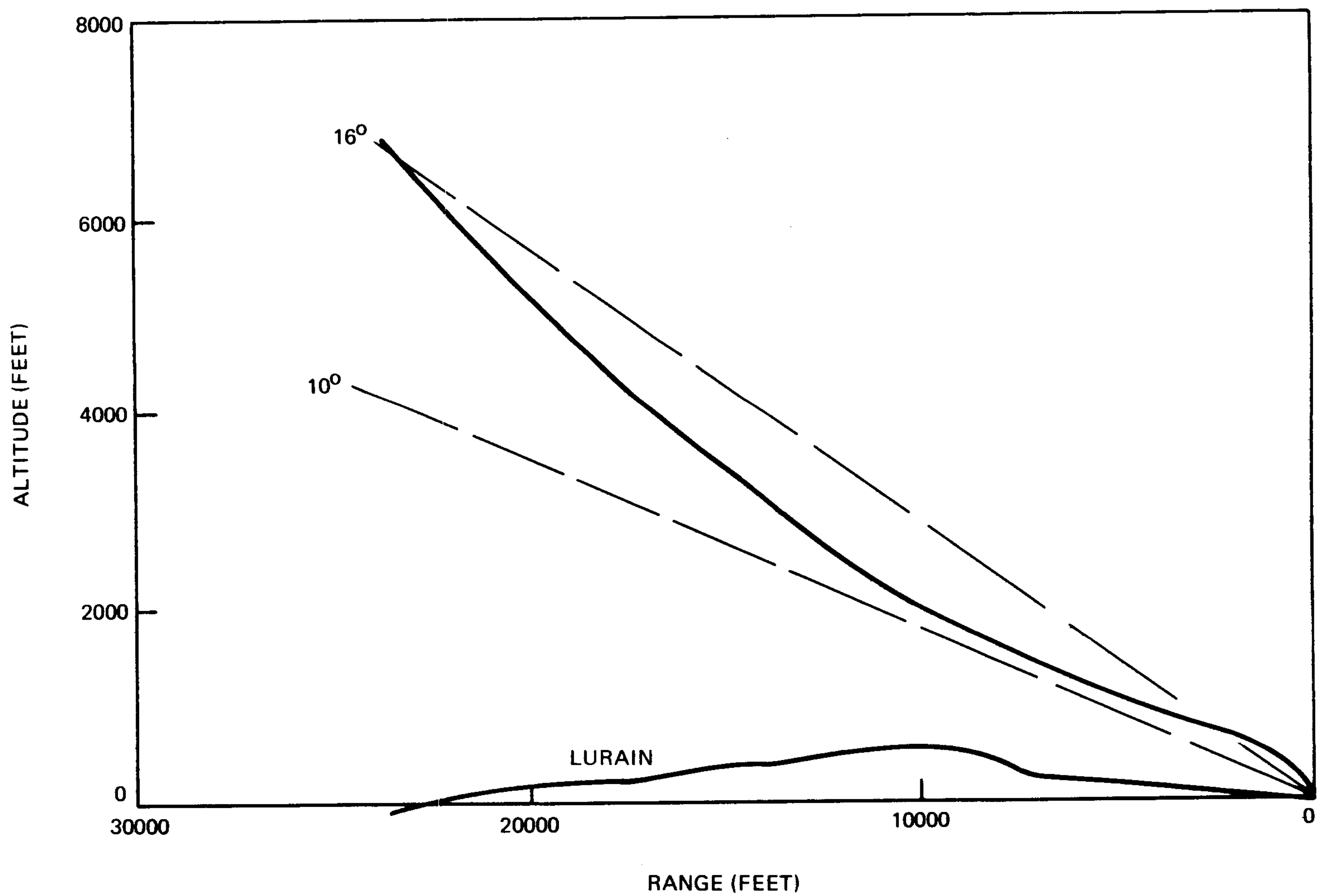

FIGURE 2–TRAJECTORY AND LURAIN PROFILES FOR CASE 2, LANDING SITE MOVED 2160 FT UPRANGE.

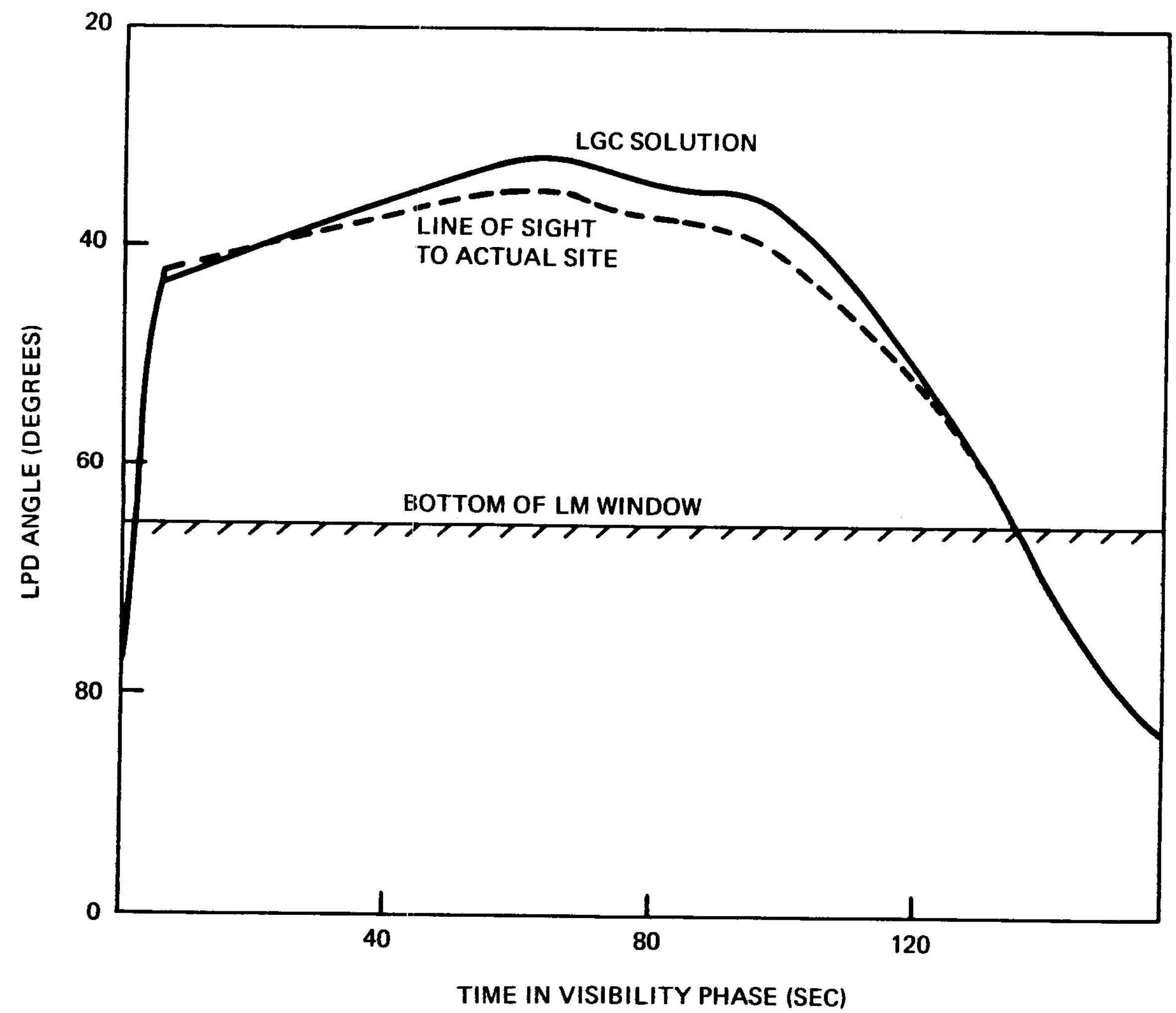

FIGURE 3—LPD ANGLE AND LINE OF SIGHT ANGLE TO THE LANDING SITE VS. TIME IN VISIBILITY PHASE FOR CASE 1.

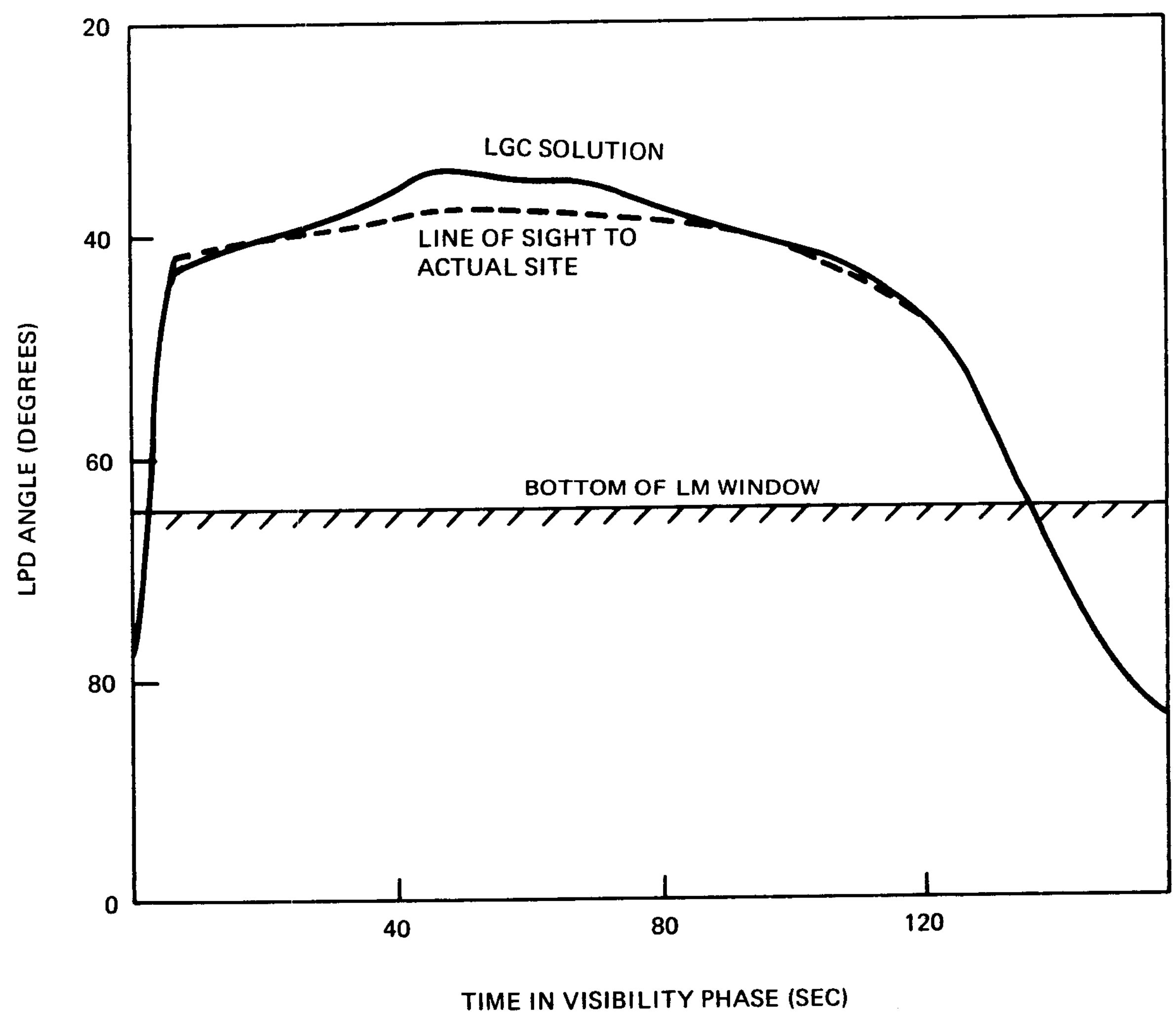

FIGURE 4—LPD ANGLE AND LINE OF SIGHT ANGLE TO THE LANDING SITE VS. TIME IN VISIBILITY PHASE FOR CASE 2.

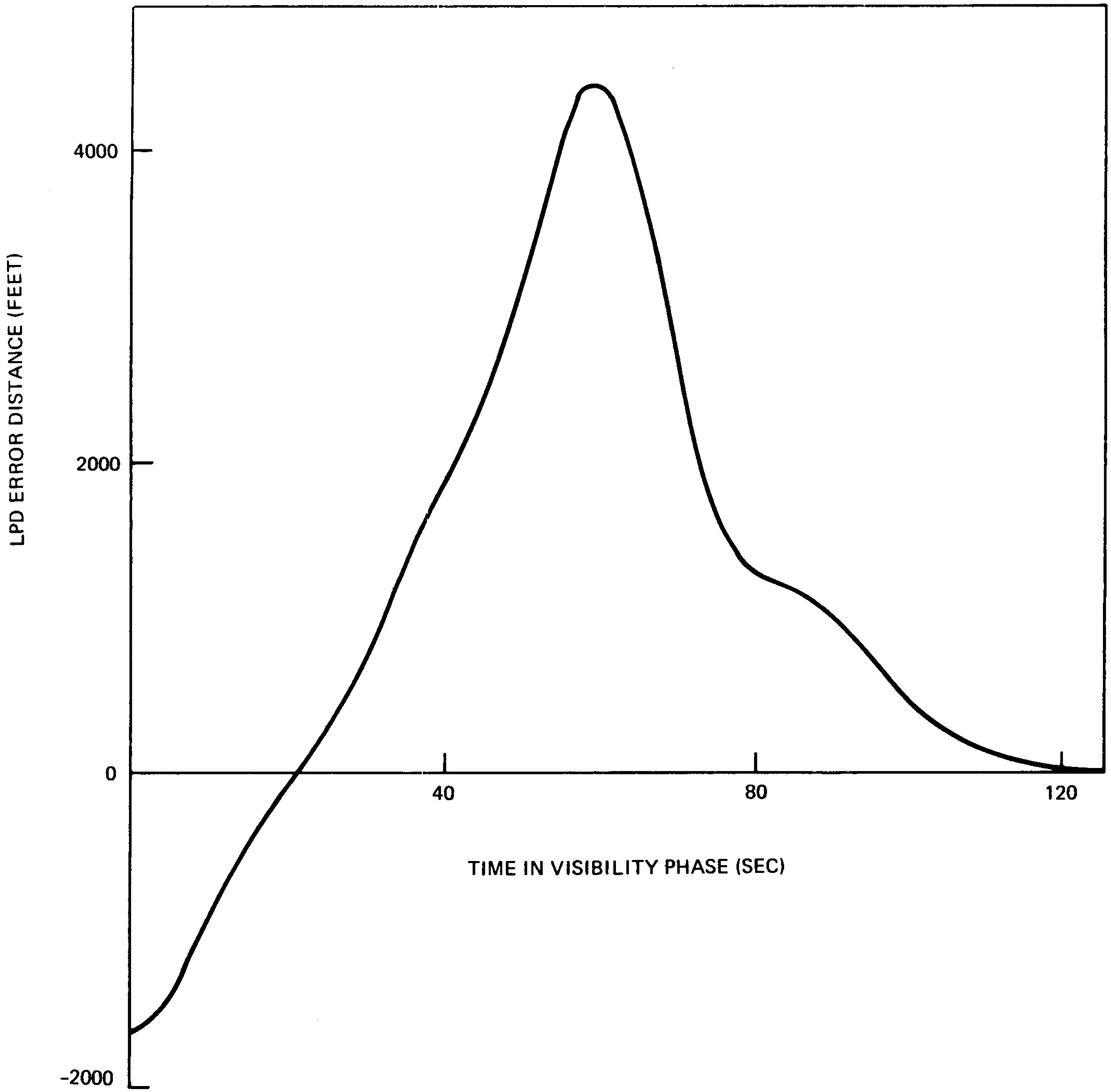

FIGURE 5—LPD ERROR DISTANCE VS. TIME FOR CASE 1.

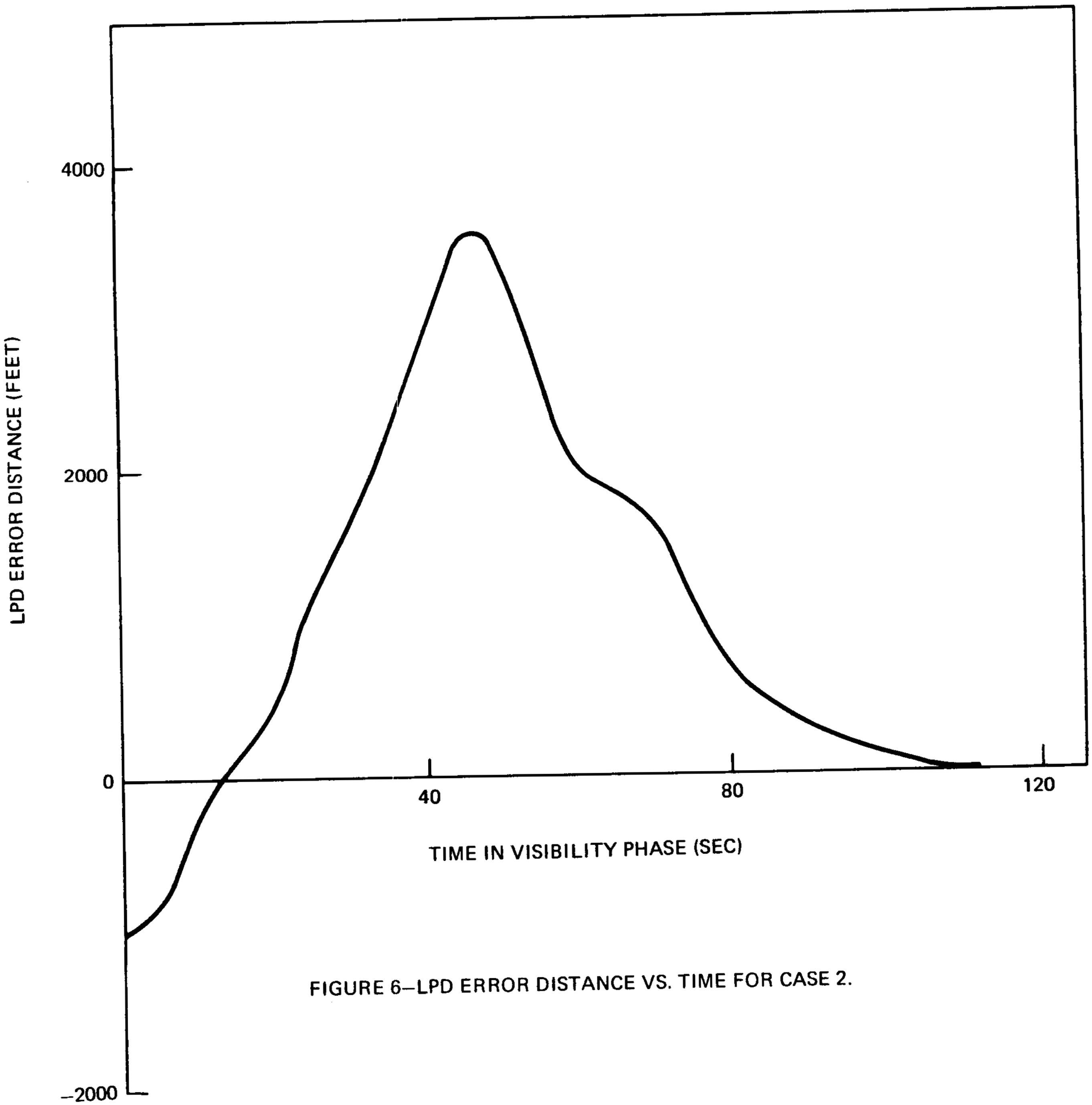

FIGURE 6—LPD ERROR DISTANCE VS. TIME FOR CASE 2.

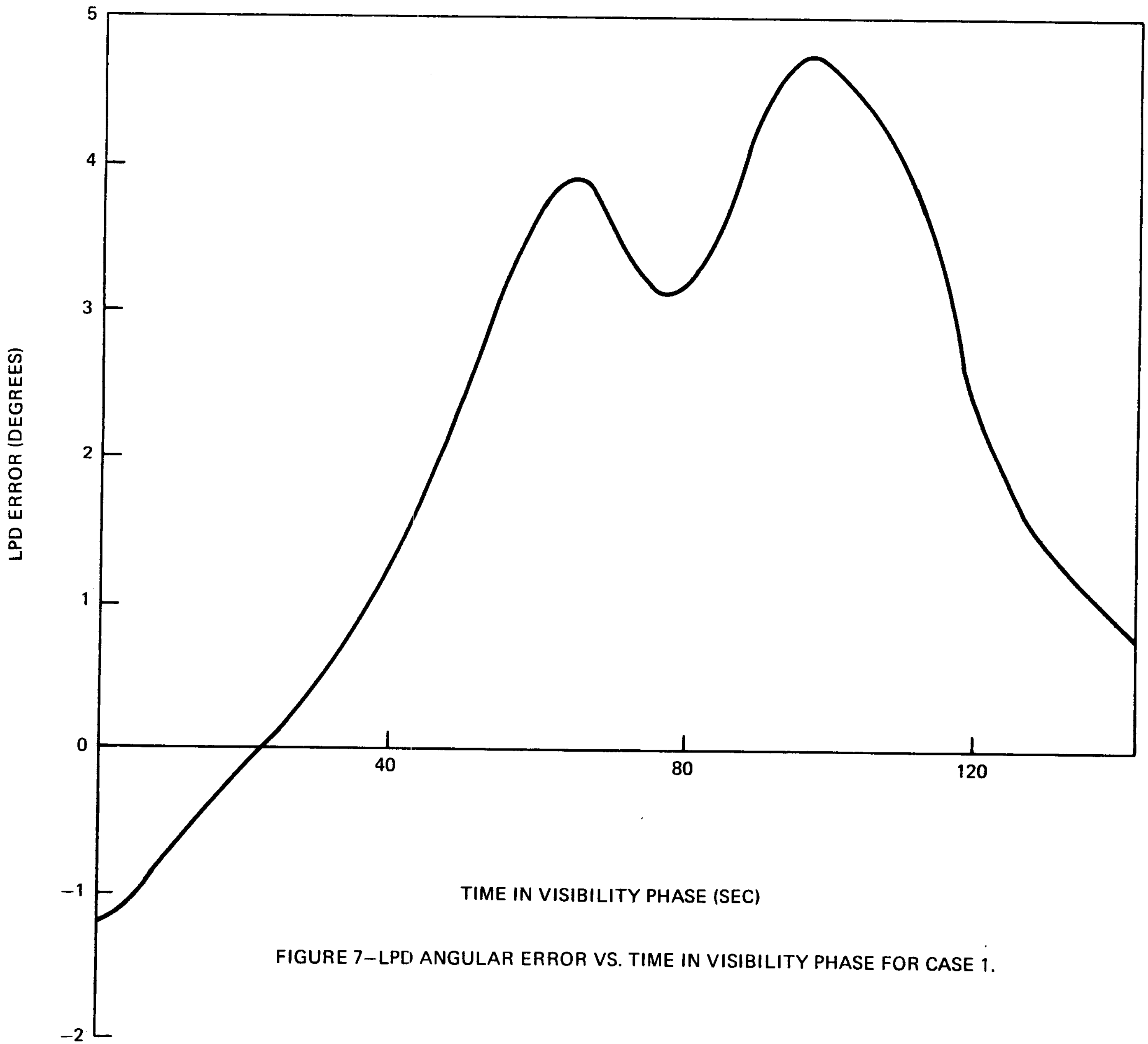

FIGURE 7—LPD ANGULAR ERROR VS. TIME IN VISIBILITY PHASE FOR CASE 1.

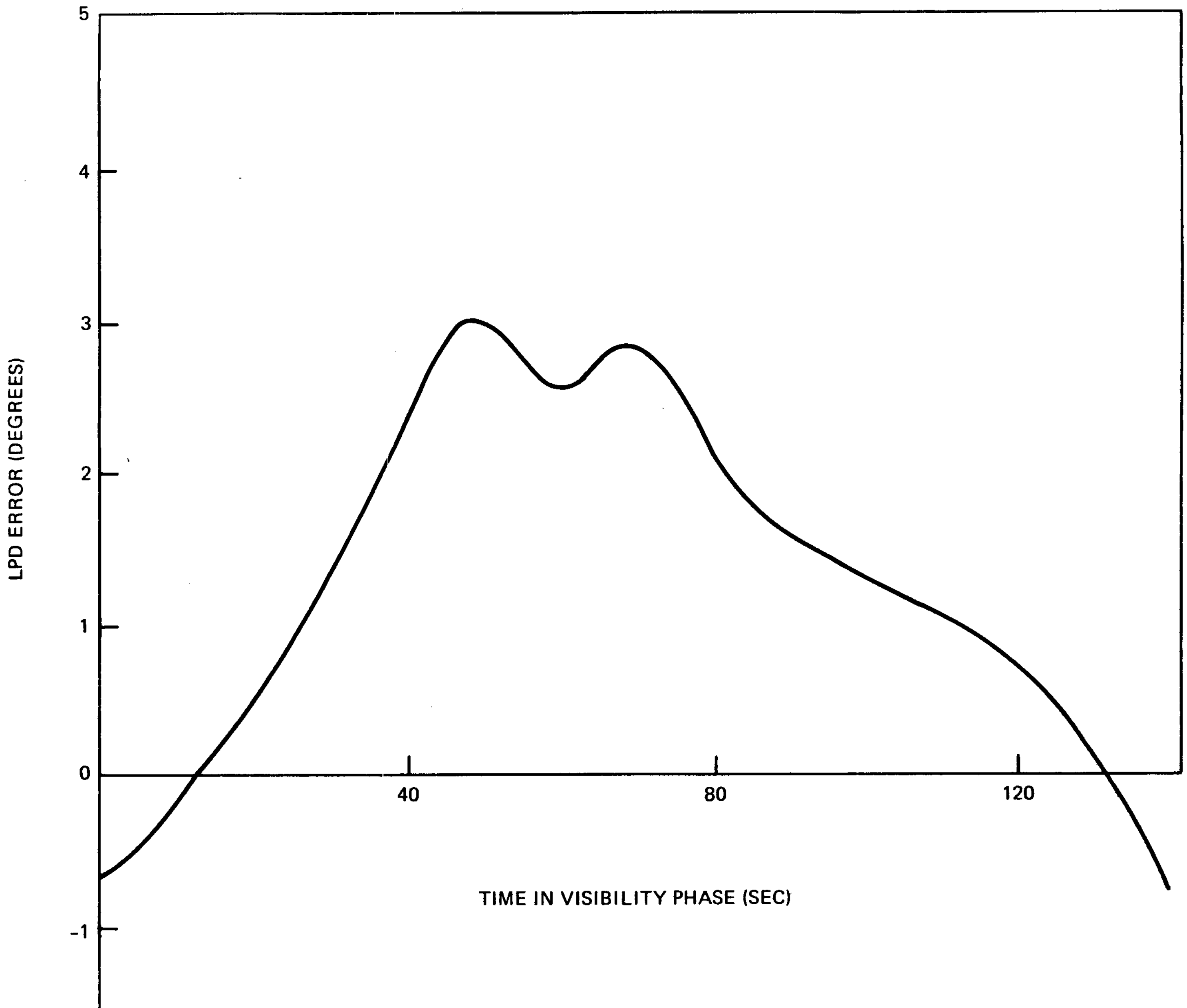

FIGURE 8–LPD ANGULAR ERROR VS. TIME IN VISIBILITY PHASE FOR CASE 2.